CHAPTER X

EVALUATING THE SEVERITY OF MOISTURE STRESS IN CORN UTILIZING REMOTELY SENSED CROP TEMPERATURE DATA

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ABSTRACT

Crop canopy temperature was measured with an infrared thermometer in four plots of corn subjected to different levels of water stress. The objectives of the research were (1) to measure crop canopy temperature at various times during the day in plots of corn subjected to different levels of water stress and to examine these data for evidence that the time of day at which large differences between well-watered and stressed vegetation (ΔT) begins is indicative of the severity of water stress and (2) to develop a stress severity index for quantifying the degree of water stress experienced by a crop.

We define a term called the stress severity index (SSI) where:

$$SSI = [(\Delta T_{a.m.})(\Delta T_{p.m.})]^{\frac{1}{2}}$$

For our $\Delta T_{a.m.}$ and $\Delta T_{p.m.}$ readings, we used data taken at 1000 and 1400 hrs solar time, respectively. Preliminary results indicate that an SSI value of zero with a postive $\Delta T_{p.m.}$ corresponds to mild or very moderate stress while an SSI value of five corresponds to severe stress. Examples of a plot with mild stress, two plots with moderate stress and one plot with severe stress were observed. A mid-morning and a mid-afternoon measurement of ΔT would seem to be very useful to accurately estimating the severity of crop water stress from crop temperature data. Further

research is needed to quantify the relationships between SSI values and the severity of crop water stress. Once these relationships have been developed, the use of the SSI or a similar approach should be useful for monitoring crop water stress from airborne or satellite-borne thermal scanners.

INTRODUCTION

Gardner et al. (Chapter V) reported that temperature differences (ΔT) between water stressed and non-stressed corn (Zea mays L.) do not, generally, develop before solar noon. In one experimental plot, however, positive ΔT values developed in the early morning. We postulated that the severity of stress may be indicated by the time of day at which stress develops. Severely stressed plants should exhibit positive values of ΔT in early or mid-morning while mildly to moderately stressed plants would develop positive values only after solar noon.

The major objectives of the research reported here were (1) to measure crop canopy temperature at various times of day in plots of corn subjected to different levels of water stress and to examine these data for evidence that the time of occurrence of large ΔT values may be indicative of the severity of water stress and (2) to develop a stress severity index for quantifying the degree of water stress experienced by a crop.

MATERIALS AND METHODS

Experiments were conducted at the Sandhills Agricultural Laboratory. Crop canopy temperatures were measured with a Telatemp Model Ag-42[1] infrared thermometer (IRT) at a viewing

[1]Telatemp Corp., P.O. Box 5160, Fullerton, CA (model Ag-42).

angle of approximately 20° from the horizontal. Measurements were made hourly between 0900 and 1500 hrs (solar time) on August 1 and August 3, 1979. ΔT values were determined by subtracting the average temperature of row 2 in plots 1 through 11 from the average temperature in plot 35 or the temperature of row 22 in plots 6, 8, 10 (Fig. 1). Row 2 data provide the average temperature of fully irrigated plants. Row 2 data are from water stressed plants. Plot 35 was a dryland plot in the plant population study which was very severely stressed for water.

RESULTS AND DISCUSSION

Prior to solar noon on August 1, 1979, ΔT was found positive only for plot 35 (Fig. 2). By 1400 hours ΔT was positive in plots 8, 10 and 35. On August 3, 1979, ΔT was positive at 1000 hours in all plots except plot 6 and by 1400 it was positive in all plots (Fig. 3). It seems that the level of stress was increasing with time in the four non-irrigated plots. The severity of stress was highest in plot 35 on both dates. In plot 6 no stress was evident on August 1 but by August 3 some plants were beginning to experience stress in that plot.

In order to use crop temperature data to quantify stress level, we have defined a term called the stress severity index (SSI), as a function of ΔT, where:

$$SSI = [(\Delta T_{a.m.})(\Delta T_{p.m.})]^{\frac{1}{2}}$$

We selected ΔT readings at 1000 and 1400 hours solar time for the a.m. and p.m. readings, respectively. There may be better times, especially the a.m. reading, which may be chosen should

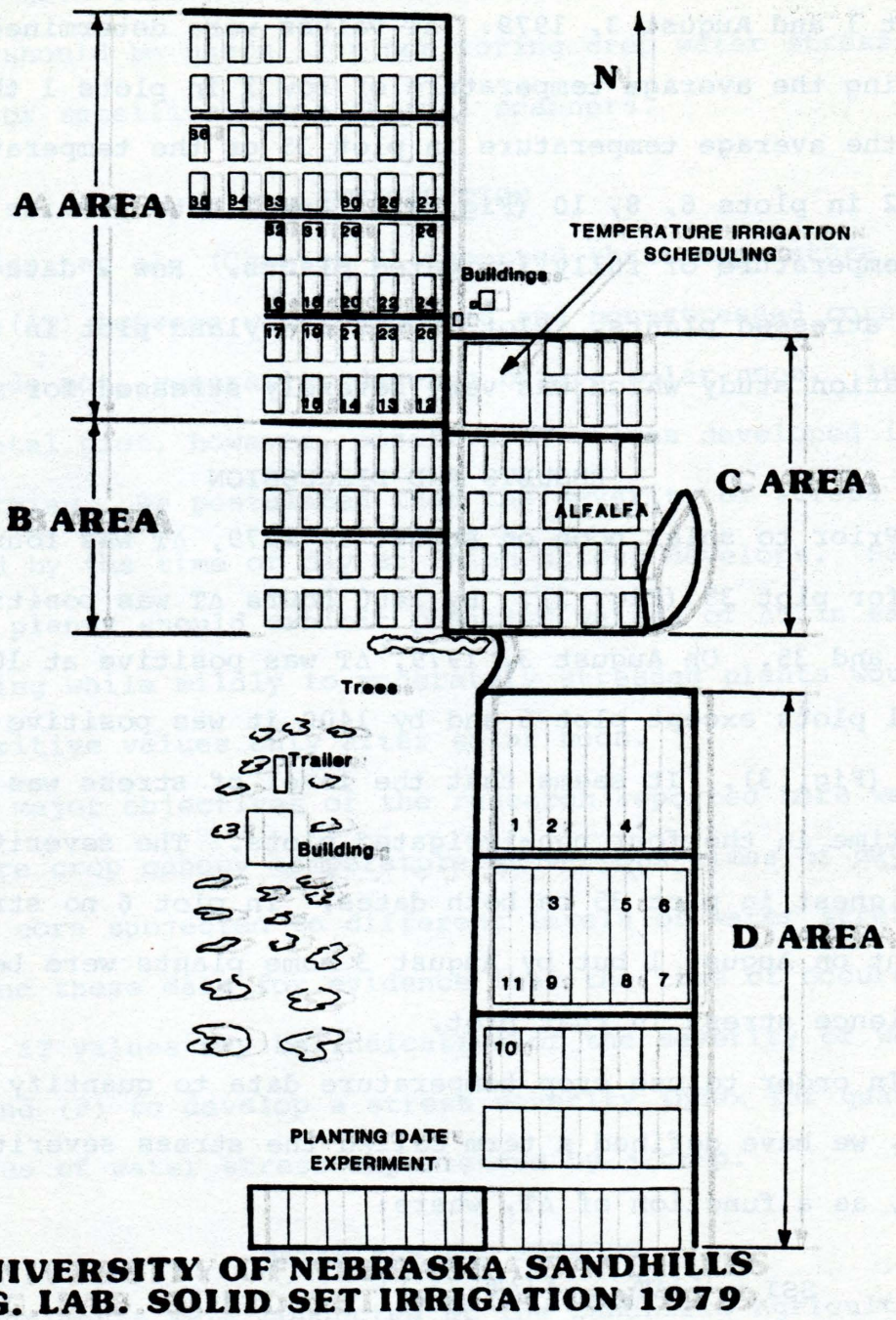

Fig. 1. Location of plots used in moisture stress severity study. Plots used in study are numbers 1-11 and 35.

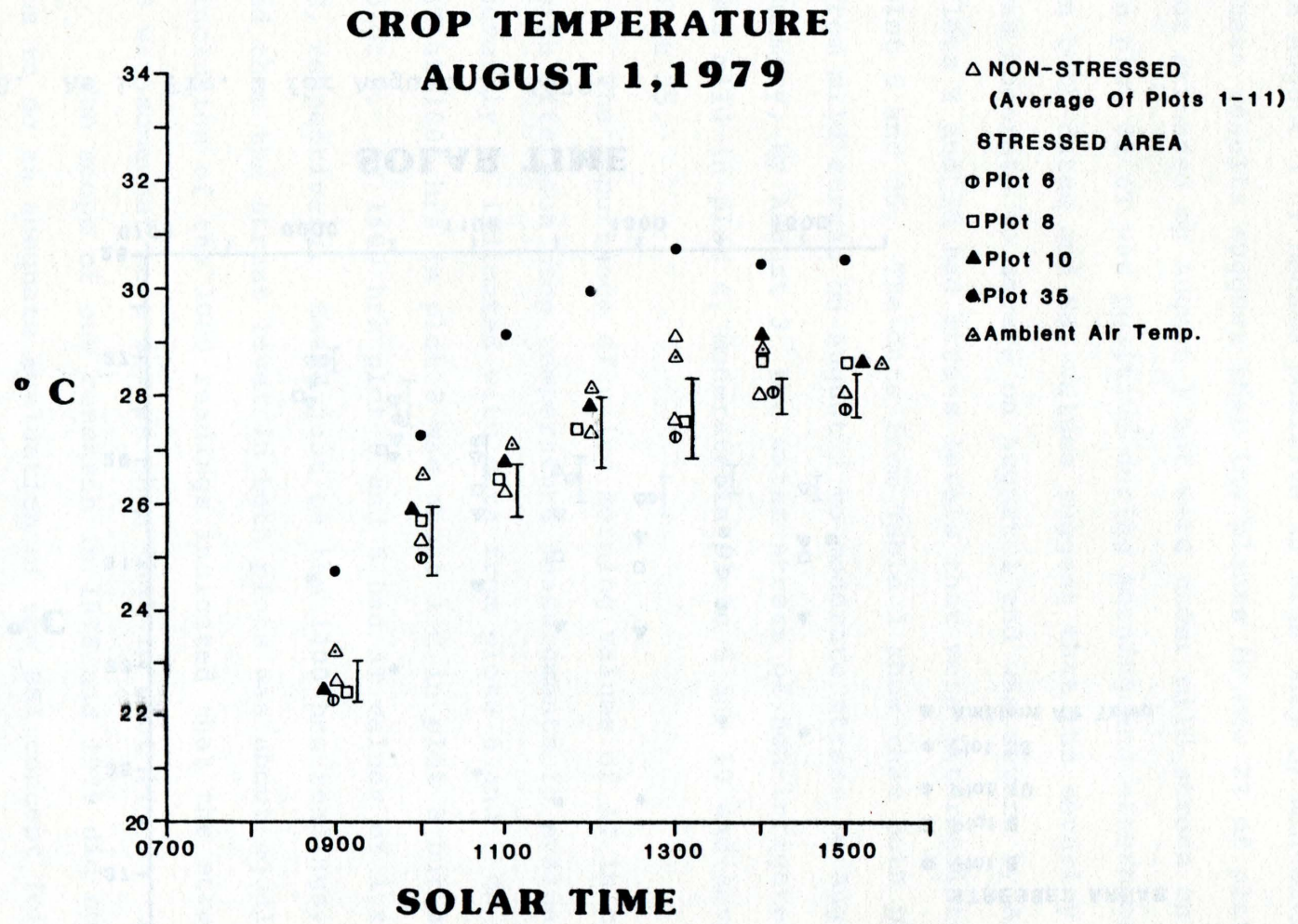

Fig. 2. Crop temperature of corn in four water stressed plots and the average of 11 non-stressed plots during 0900-1500 hrs on August 1, 1979. The bars indicate the range in temperature of the well-watered plots.

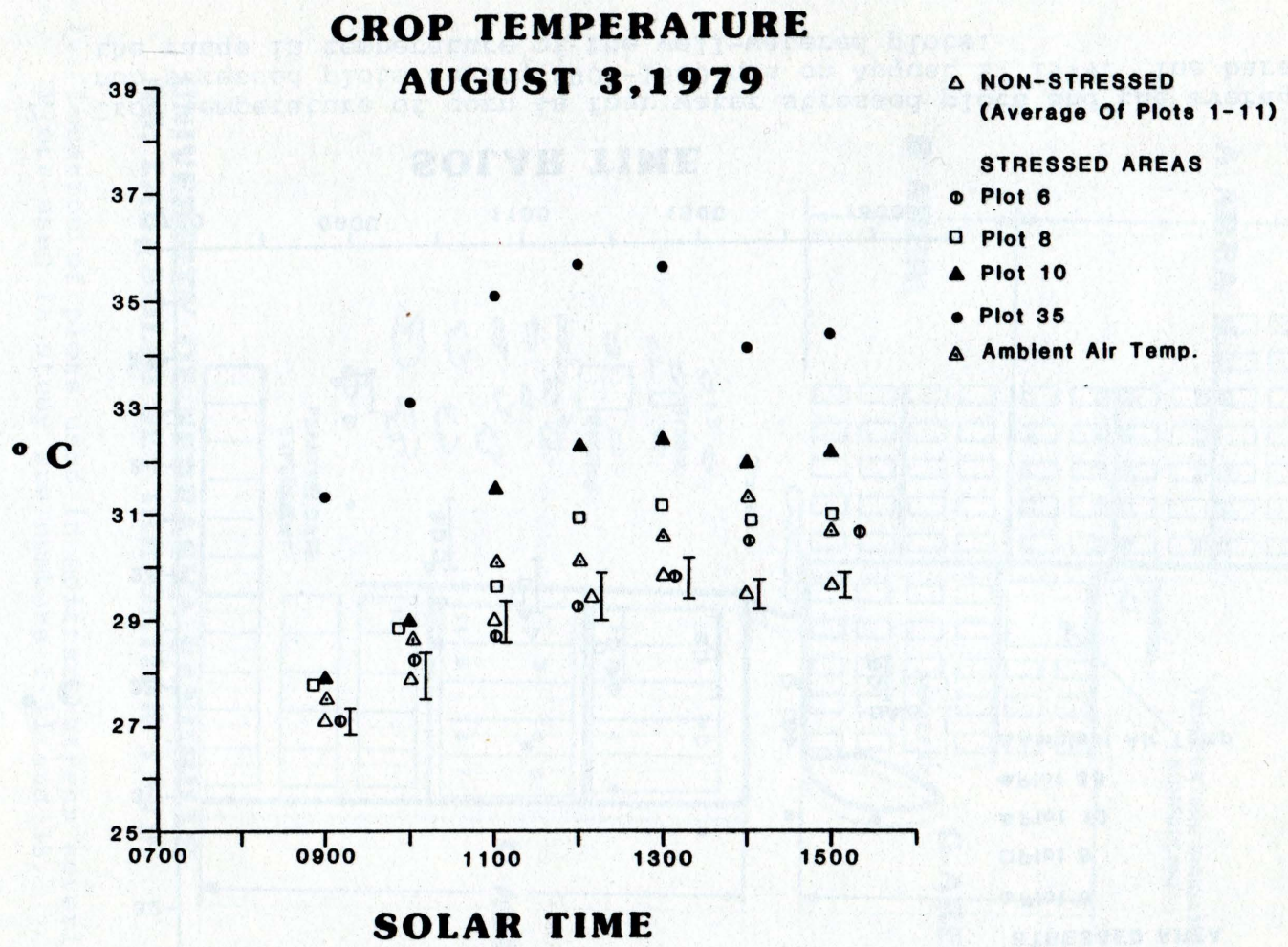

Fig. 3. As in Fig. 2 for August 3, 1979.

further study indicate the desirability of doing so.

SSI values for the four plots we evaluated are in Table 1. In plot 6 morning and afternoon ΔT values were zero on August 1. On August 3 ΔT became positive in sign only by mid-afternoon. These results suggest that the plants in row 22 of plot 6 were not stressed on August 1 but were under mild stress on August 3. In plot 35 ΔT was positive during morning and afternoon periods on both dates and SSI values suggest that the severity of stress was moderate to severe on August 1 and was severe by August 3. Plots 8 and 10 had stress levels that were intermediate between plot 6 and 35. The data from Table 1 show that both plots went from mild stress on August 1 to moderate stress by August 3. In summary, by August 3 the water stress of non-irrigated plants was mild in plot 6, moderate in plots 8 and 10 and severe in plot 35.

The importance of using morning values of ΔT in conjunction with afternoon crop temperature measurements to evaluate stress severity is indicated with data from plots 6 and 8 on August 3. ΔT at 1000 hrs in plot 8 was about 1 C in plot 8 but zero in plot 6. At 1400 hrs plot 8 and 6 had ΔT values of 1.4 and 1.0 C, respectively. Based just on the 1400 hrs readings, it appeared that the stress level in both plots was about equal. However, inclusion of the 1000 readings indicated that the stress in plot 8 was somewhat more severe than that in plot 6.

The scope of our research in 1978 and 1979 did not permit us to do an adequate evaluation of the SSI concept for estimating crop water stress. We are confident that the SSI approach or something similar will be very useful in monitoring crop water

Table 1. Stress Severity Index (SSI) values for four non-irrigated plots, where:

$$SSI = [(\Delta T_{mid\text{-}morning})(\Delta T_{mid\text{-}day})]^{\frac{1}{2}}$$

ΔT is the difference in temperature (C) between an irrigated and non-irrigated area. Mid-morning and mid-day values were computed for 1000 and 1400, respectively.

	ΔT		August 1	ΔT		August 3
Plot	1000	1400	SSI	1000	1400	SSI
6	0	0	0.0	0	1.0	0.0*
8	0	0.7	0.0*	0.8	1.4	1.1
10	0	1.2	0.0*	1.1	2.5	1.7
35	1.9	2.4	2.1	5.1	4.6	4.8

*Stress levels were mild to moderate since only $\Delta T_{p.m.}$ was positive.

stress with temperature data from airborne or satellite-borne thermal scanners. Further research is needed, however, to quantify relationships between SSI values and the severity of crop water stress.

Preliminary analysis of our data suggests that an SSI value of zero in conjunction with a positive $\Delta T_{p.m.}$ value corresponds to mild or, perhaps, very moderate stress. An SSI value approaching five indicate severe stress. It is uncertain, at this time, whether or not a given SSI value will correspond to a given stress level. It appears certain, however, that SSI values can be used to compare the relative level of stress from one field to another. Measurements of plant water stress, including plant water potential and stomatal diffusive resistance, are needed in conjunction with crop canopy temperature measurements for the major agronomic crops before the SSI concept can be adequately evaluated.

Since fluctuations in various environmental conditions can cause variation in mid-day ΔT measurements, we suggest that mid-morning ΔT measurements will aid in the interpretation of the mid-day canopy temperature data. In fact, mid-morning and a mid-afternoon measurement of ΔT is essential if crop temperature data are to be used for accurate estimation of the severity of crop water stress.